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# THE CONNECTION OF METRICS OF VISUAL AND AUDIO SPACES FOR A METHOD OF TRANSFORMING AN IMAGE INTO SOUND

by

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# UNEDITED ROUGH DRAFT TRANSLATION

# THE CONNECTION OF METRICS OF VISUAL AND AUDIO SPACES FOR A METHOD OF TRANSFORMING AN IMAGE INTO SOUND

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ABSTRACT

The author elsewhere proposed and studied experimentally (Doklady XXI Vsesoyuznoy nauchoy sessii NTOR i E. Bionika, M., 1965) methods for image-to-sound conversion aiming at unburdening the vision of operators. It is of interest to study the given transformation algorithm from the point of view of general criteria of the pattern recognition theory without direct connections with operator psychology. Consequently, the criteria, such as the interval between the classes of images and metric parameters of classes in N-dimensional index spaces within which one can realize (as points) arbitrary classes, are investigated mathematically. Technical limitations are compared with the results of mathematical simplifications of the exact theory. Orig. art. has: 21 formulas.

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# THE CONNECTION OF METRICS OF VISUAL AND AUDIO SPACES FOR A METHOD OF TRANSFORMING AN IMAGE INTO SOUND

V. G. Grishin

Previously [1, 2] was proposed and experimentally investigated a method of transforming an image into sound for the purpose of relieving the operator's vision and expanding its possibilities. All our reports devoted to this transformation method, were based on a certain model of aural perception.

It is interesting, evidently, to investigate the given transformation algorithm also from the viewpoint of general criteria of the theory of recognizing pictures, having no direct connection with the psychophysiology of the operator.

Such criteria appear to be distinction between classes of pictures and metric parameters of classes in N-dimensional space of signs, in which any possible realization of any given class is represented by a point. If in role of signs of our initial visual pictures are selected brightnesses of their individual points, then to each image will correspond a point (vector) in N-dimensional space, where N — is determined by the required according to problem conditions discrimination of picture details — resolving power. Considering the N-dimensional space of signs euclidean, we will obtain the following expression for the distance between points a and v:

$$R(a, b) = \sqrt{\sum_{n=1}^{N} (a_n - b_n)^2}; \qquad (1)$$

In our case, when the initial depictions F(x, y) are spread by y on n-equal bands, and by x they are considered continuous and in general case with infinite resolving power, expression (1) is transformed into form

$$R^2(F, F^1) = \sum_{k=1}^{n} \int_0^{l_1} [\varphi_k(x) - \varphi_k{}^1(x)]^2 dx, \qquad (2)$$

where

$$\varphi_k(x) = \int_{y_k}^{y_{k+1}} F(x, y) dy; \qquad (3)$$

h – width of band $y_k$ (line), equalling $\ell_2/n$, $\alpha$, $\ell_1$ and $\ell_2$ – area boundaries of designating F(x, y).

The investigated transformation of each input picture places a conformal time function f(t) on the designation interval [0, T] by the law

$$f(t) = \sum_{k=1}^{n} \varphi_k(at) \sin(\omega_k t + \psi_k) \qquad (4)$$

where $\phi_k(x)$ and $\omega_k$ are determined above, $\psi_k$ – initial phase of the carrier, and x with t are bound by ratio $x = \ell_1/T$. (5)

Introducing a euclidean metrics into the space of signs of synthesized functions f(t), we will obtain for function f(t) and $f^1(t)$ corresponding to functions F(x, y) and $F^1(x, y)$ a distance

$$r^2(f, f^1) = \int_0^T [f(t) - f^1(t)]^2 dt. \qquad (6)$$

Substituting in this expression (4), we will obtain

$$r^2(f, f^1) = \int_0^T \left[ \sum_{k=1}^{n} \varphi_k(at) \sin(\omega_k t + \psi_k) - \sum_{k=1}^{n} \varphi_k{}^1(at) \cdot \sin(\omega_k t + \psi_k{}^1) \right]^2 dt. \qquad (7)$$

Having grouped the subintegral expression by identical indices, we will come to an expression:

$$r^2(f, f') = \int_0^T \left\{ \sum_{k=1}^n [\varphi_k(at) - \varphi_k^1(at)] \sin(\omega_k t + \psi_k)^2 \right\} at. \qquad (8)$$

The change in form

$$\delta_k(t) = \varphi_k(at) - \varphi_k^1(at) \qquad (9)$$

gives

$$r^2(f, f^1) = \int_0^T \left[ \sum_{k=1}^n \delta_k(t) \sin \omega_k t + \psi_k) \right]^2 dt \qquad (10)$$

which after squaring leads to an expression:

$$r^2(f, f^1) = \int_0^T \sum_{k=1}^n \delta_k^2(t) \sin^2(\omega_k t + \psi_k) dt +$$

$$+ \int_0^T \sum_{k, l}^n \delta_k \delta_l \sin(\omega_k t + \psi_k) \sin(\omega_l t + \psi_l) dt \qquad (11)$$

where $l$ – independent from k index, acquiring the very same values, as k, whereby $l \neq k$.

The first integral (11) can be written so:

$$A = \frac{1}{2} \int_0^T \sum_{k=1}^n \delta_k^2(t) dt - \frac{1}{2} \int_0^T \sum_{k=1}^n \delta_k^2(t) \cos 2(\omega_k t + \psi_k) dt. \qquad (12)$$

But the first member of this expression is nothing else than (2) after substituting here (5), i.e., (12) can be recorded

$$A = \frac{R^2(F, F^1)}{2a} - \frac{1}{2} \int_0^T \sum_{k=1}^n \delta_k^2(t) \cos 2(\omega_k t + \psi_k) dt. \qquad (13)$$

Assuming that $\delta_k^2(t)$ is a slowly changing function as compared with cos $2\omega_k t$ and adopting known trigonometric transformations, we will obtain from (13) the following expression:

$$A = \frac{R^2}{2} \sum_{k=1}^n \cos 2\psi_k \frac{\sin 2\omega_k T}{2\omega_k} \delta_k^2(T) -$$

$$\sum_{k=1}^n \sin 2\psi_k \left[ \frac{\delta_k^2(T)}{2\omega_k} \cos 2\omega_k T - \frac{\delta_k^2(0)}{2\omega_k} \right] dt. \qquad (14)$$

At this assumption we transform the second integral of equation (12), as result of which we will obtain:

$$\begin{aligned} r^2(f, f^1) = {} & \frac{R^2}{2a} + \sum_{k=1}^{n} \cos 2\psi_k \frac{\sin 2\omega_k T}{2\omega_k} \delta_k^2(T) - \\ & - \sum_{k=1}^{n} \sin 2\psi_k \left[ \frac{\delta_k^2(T)}{2\omega_k} \cos 2\omega_k T - \frac{\delta_k^2(0)}{2\omega_k} \right] - \\ & - \sum_{k=1}^{n} \left[ \frac{2\delta_k(T)\delta_l(T)}{\omega_k + \omega_l} \sin\left( \frac{\omega_k + \omega_l}{2} T + \frac{\psi_k + \psi_l}{2} \right) - \right. \\ & \left. - \frac{2\delta_k(0)\delta_l(0)}{\omega_k + \omega_l} \sin \frac{\psi_k + \psi_l}{2} \right] + \\ & + \sum_{k, l}^{n} \frac{2\delta_k(T)\delta_l(T)}{\omega_k - \omega_l} \sin\left( \frac{\omega_k - \omega_l}{2} T + \frac{\psi_k - \psi_l}{2} \right) - \\ & - \frac{2\delta_k(0)\delta_l(0)}{\omega_k - \omega_l} \sin \frac{\psi_k - \psi_l}{2} \Bigg]. \end{aligned} \tag{15}$$

We will analyze the obtained expression.

1. Having fixed for given visual pictures boundary conditions of form

$$\varphi_k(0) = \varphi_k^1(0) \quad \text{and} \quad \varphi_k(l) = \varphi_k^1(l), \tag{16}$$

we will obtain from (15)

$$r^2(f, f^1) = \frac{R^2}{2a} \quad \text{or} \quad r(f, f^1) = \frac{R(F, F^1)}{2a}, \tag{17}$$

i.e., at these limitations, applied on functions F(x, y), the distances between the formed accoustic pictures in space of their signs differ from corresponding distances between the initial signs only at a constant multiple.

It is evident, that requirement (16) can be easily realized practically in form of a mask at recoder input with transparency in change along axis x by any of the rules shown in Fig. 1 or having organized a change in sensitivity of the photo field along axis X by any one of these dependences. Whereby the rate of increasing the sensitivity or transparency with the removal from

$X = 0$ and $X = \ell_1$ is bound with the above posted requirement of slowness in change $\psi_k(X)$ after comparing with the carrier oscillations.

It can easily be seen, that the proposed technical realizations are equivalent to much more stronger, than (16) limitations, which can be written so:

$$\varphi_k(0)=\varphi_k^1(0)=\varphi_k(l_1)=\varphi_k^1(l)=0. \tag{18}$$

This equality should be understood, apparently, not as a requirement to initial visual pictures, but as result of above described processing of same at the input of the installation. Naturally, that in this case is lost the entire information about boundary areas with $X = 0$ and $X = \ell_1$.

2. Possible are also other simplifications of formula (15). Actually, placing $\omega_k = c^k\omega_H$ and $\omega_H = 2\pi/T\ b$, where b and c are any integral positive numbers, i.e., placing all carrier frequencies of the recoder as integral multiples of the sounding period of the entire picture (period of reading the visual picture) T, we will obtain

$$\begin{aligned} r^2(f, f^1) = {} & \frac{R^2}{2a} - \sum_{k=1}^{n} \sin 2\psi_k \left[\frac{\delta_k^2(T)-\delta_k^2(0)}{2\omega_k}\right] + \\ & + \sum_{k,l}^{n} [2\delta_k(T)\delta_l(T) - 2\delta_k(0)\delta_l(0)] \left(\frac{\sin\frac{\psi_k-\psi_l}{2}}{\omega_k-\omega_l} - \frac{\sin\frac{\psi_k+\psi_l}{2}}{\omega_k+\omega_l}\right] \end{aligned} \tag{19}$$

At $\psi_k = \psi_1 = 0$, i.e., at zero initial phases of all carriers for any k and $\ell$ (19) is reduced to (17). An analogous situation originates also during equality $\delta_k(T) = \delta_k$, equivalent to a much weaker, than (16) requirement:

$$\varphi_k(0)-\varphi_k^1 0=\varphi_k(l)-\varphi_k^1(l) \tag{20}$$

Above we imposed on $\delta^2(t)$ a slowness of change requirement in comparison with $\sin 2\omega_k t$, which is practically equivalent to the requirement of change slowness $\phi_k(t)$ in comparison with $\sin \omega_k t$, necessary for picture coincidence of instant spectrum of signal f(t) formed by transformation with initial picture F(x, y) [2]. This fact confirms the internal bond of the approach to transformation, emanating from the adopted by us model of aural perception, and the pure mathematical approach to this problem.

The very requirement of change slowness $\phi_k(t)$ in comparison with sin $\omega_k t$ is equivalent to the smallness requirement of Fourier series coefficients, in which $\phi_k(t)$ is decomposed at members with frequencies, comparable and greater than $\phi_k$. This condition can also be expressed in another way:

$$\frac{2\pi}{\omega_k} \cdot \frac{d\varphi_k(t)}{dt} \ll \varphi_k(t) \tag{21}$$

for any given t and k, which can be determined as a smallness in absolute increment of function $\phi_k(t)$ by an interval equal to the period of frequency $\omega_k$ in comparison with the value of the very function in this interval. Since the rate of change $\phi_k(t)$ depends upon the time of reading the image $T(X = \ell_1/T \cdot t)$, then the above described requirement is practically reduced to a requirement of increasing T, leading to a reduction in rate of change of X in dependence upon t, and consequently, also to a reduction in rate of change $\phi_k(x) = \phi_k(\ell_1/T \cdot t)$ in comparison with sin $\omega_k t$.

## Literature

1. Grishin, V. G. Doklady XXI Vsesoyuznoy nauchnoy sessii NTOR i E (Reports of XXI All Union scientific session NTOR and journal). Bionika. Moscow, 1965.

2. Grishin, V. G. Zritel'naya model' slukhovogo analizatora (Visual model of aural analyzer). Doklady II Vsesoyuznoy konferentsii po bionike, Moscow, 1965.

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